

**Weed Science, PLS 4601c Section 7644
and Grad. – Prin. Of Weed Science AGR 6932 Section 9212
University of Florida - Davie
<http://grove.ufl.edu/~turf/weedscience/>
Philip Busey, turf@ufl.edu
954-579-3932 (cell)
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Weed Science – Learning Concepts

A. Introduction

1. There is a useful biological definition of “weed”

A weed is a plant that is adapted to disturbed habitats. Weeds occur in nature as first stage colonists after cataclysms such as earthquakes and landslides, they invade dung patties and grow along cattle paths, and they follow the trail of human settlement and disturbance.

A commonly used definition, “a weed is a plant that is not desired,” does nothing to advance scientific understanding. The official Weed Science Society of America (WSSA) definition of a weed is unclear, “a plant originating under natural conditions and in response to imposed environments that interferes with human activity.” What is an imposed environment? How do invasive exotic in natural areas interfere with human activity?

As weeds continue to evolve under selection pressure for reproduction in disturbed habitats, particularly farmers’ fields, it is likely that weeds will originate under the artificial conditions imposed by people.

2. Weeds provide benefits

Dooryard weeds are useful potherbs and provide vitamins and minerals. Weeds are sometimes progenitors or sister ecotypes of useful cultivated species, and weeds provide reservoirs of genes for pest resistance in the crops. Many of the useful ground cover species including some turfgrass species are weeds or weedy. Other weeds such as Madagascar periwinkle provide beneficial drugs.

3. Weeds harm public health and safety, agriculture, and the environment

Ragweed and other pollen producing species can be allergenic to humans, causing “hayfever,” and loss of work productive, rashes, and some are poisonous especially to children, pets, and animals raised for food. Crop yield losses, loss of quality, loss of harvest efficiency, difficulties in processing, and the cost of herbicides and other practices for reducing weed infestation account for billions of dollars per year in U.S. agriculture. Most of the weed losses are in row crops but the burden of weed

control is great on human cultivators. Much of the expense of fertilizer goes to grow weeds and is unavailable to crops because the weeds are competing for fertilizer and other resources. Some weeds such as witchweed (*Striga*) have no chlorophyll and are obligate parasites often attached by haustoria; other weed parasites have chlorophyll. Weeds are nuisances that affect driver visibility; clog canals needed to prevent flooding and reduce damage. Weeds can have thorns and other structures to attach to people and their clothing, and be alternate hosts for plant disease organisms, such as the virus maize dwarf mosaic which can move from johnsongrass to maize. Weeds reduce property values and harm the environment.

4. Invasive species are becoming a great problem in natural areas

Although many pasture grasses and other potentially useful plants were intentionally introduced to the U.S. from other continents, some have become a huge problem in natural areas. Woody exotics such as *Melaleuca quinquenervia* take away the habitat from wildlife and make properties unusable. Of all the forms of biological disturbance caused by people (habitat loss, pesticide and nutrient pollution, and species introduction) probably the longest acting and most permanent problem involves species introductions. Weeds can displace native plants. Vine weeds, e.g., Old World climbing fern, can be quite destructive.

5. Some weeds are outlaws

The Federal Seed Act of 1939 protected farmers from new foreign introductions from, “any weed or plant that is so declared by an authoritative group, with the legal power to make such a declaration, to be harmful or possess noxious characteristics.”

The Federal Noxious Weed Act of 1974, and revised subsequently, regulates the importation of noxious weeds defined as, “any living stage (including, but not limited to, seeds and reproductive parts) of any parasitic or other plant, of a kind or subdivision of a kind, which is of foreign origin, is new or not widely prevalent in the United States, and can directly or indirectly injure crops, or useful plants, livestock, poultry, or other interests of agriculture or irrigation, or navigation, or the fish, or wildlife resources of the United States or public health.”

There are state laws and county ordinances prohibiting the use of dangerous invasive plants. There are also local landscaping ordinances that prohibit homeowners from allowing their lawns to grow up in weeds.

B. Kinds of Weeds

6. Plants are classified in related groups and the groups are named

The genus name + species name form a binomial, the scientific name, to describe in Latin a particular type of plant, e.g., annual bluegrass (*Poa annua*). The binomial is written in italicized font. Species are grouped within a genus, and the genera (plural of genus) are grouped in families, which are grouped in orders, which are grouped in classes, which are grouped in phyla. There are intermediate groupings such as sub-genus, subfamily, and subspecies. A cultivar (cultivated variety) is a trade type within a species and it is written as, *Stenotaphrum secundatum* 'Floratom' (Floratom St. Augustinegrass). Natural classification is considered to be that which is stable and robustly explains most of the variability of species, and that which is not easily changeable.

The general area of classification is called taxonomy and is based on the idea that group at different levels of organization (species, genera, families, etc.) are taxa (singular, taxon). Even though there is a formal process for naming plants and grouping (or classifying) plants, and even though this is done with care and precision and with documentation, there is no universal agreement what is a species. A plant species is that which a botanist says is a species.

Common names of plants including weeds vary by region and common language. As an example of the rich history of common names, *Paspalum notatum* has many unique common names throughout Latin America, which is consistent with its natural distribution throughout. For example, it is called "**pasto horqueta**" and "**gramilla**" and sometimes "**pasto de miel**" in Argentina, though the latter is also used to refer to the genus. In Brazil, it is called "grama batatais," to distinguish it from "**grama dulce**," which is *P. urvillei* Steud., and rarely "**forquinha**," in obvious reference to the forked appearance of the two inflorescence racemes. In Costa Rica, it is called "**gengibrillo**;" in Mexico it is called "**zacate bahía**," and "**cabeza de burro**," and sometimes "**seca sebo**" or "**zacate camalote**" or "**zacate de llanero**." Names suggesting an intentional outside introduction are from Cuba, where it is called "**pasto mexicano**" and "**Tejana**;" from the U.S., where it is called "**bahiagrass**;" and from Spain, where it is called "**hierba de Bahía**." Therefore *P. notatum* was probably introduced to Cuba and the U.S. in historical times, possibly both accidentally and intentionally, and was given the names of the places from which it was thought to have originated. It is puzzling that the Type specimen was described from the West Indies, since the early 1900s writers were concerned with introductions from southern South America.

7. A few families of flowering plants have many weeds

Families with many weeds are Poaceae (Gramineae), Asteraceae (Compositae), Cyperaceae, Amaranthaceae, Brassicaceae (Cruciferae), and Fabaceae (Leguminosae), and in warm areas Rubiaceae.

8. Artificial classification of weeds helps practitioners

Unlike botanical families, a handy way to classify weeds is in three groups, grass weeds (Poaceae), sedge weeds (Cyperaceae), and broadleaf weeds (Dicotyledoneae). Often, certain kinds of herbicides are suitable for killing weeds in only one of these three groups. What group of weeds is commonly killed with Phenoxy herbicides? Where this falls apart is with the family Commelinaceae.

9. To know weeds you should know the basic terms of plant morphology

arrangement – distal vs. basal

flower accessories of grasses – spikelet, floret, lemma, palea

flower parts – calyx (sepals), corolla (petals), and reproductive parts (below)

flower types – unisexual vs. perfect, complete vs. incomplete

fruit types – caryopsis, legume, capsule, achene, samara, berry, etc.

growth habit – creeping or bunch

inflorescence types - spike, raceme, panicle, head, cyme, umbel, solitary; determinate vs. indeterminate

leaf arrangements - opposite vs. alternate vs. whorled; simple vs. compound; peltate; pinnate vs. palmate; rosette

leaf edges - serrate, incised, cleft, peltate, entire

leaf parts - petiole, blade, stipule, interpetiolar stipules, leaflet, petiolule,

leaf parts of grasses - blade, sheath, collar, ligule

life cycle – annual (winter or summer), biennial, and perennial

reproductive parts, female - ovary, pistil stigma, style, carpel, locule, ovule, fruit, seed, megaspore

reproductive parts, male – anther, filament, pollen, stamen, microspore

reproductive types – dioecious, monoecious, perfect flowers

roots – taproot, root hair, etc.

shapes – zygomorphic vs. actinomorphic, ovate, obovate, lanceolate, oblanceolate, linear

stem types - rhizome, stolon, corm, tuber, bud, crown, node, internode, bulb, culm, tiller, runner, woody vs. herbaceous, intercalary meristems (grasses)

surfaces - pubescence, spines, cuticle, glaucous (waxy), may help affecting boundary layer and may affect moisture relations

vascular system – veins, midrib, phloem, xylem, secondary xylem (wood), bark

10. Not all weeds are flowering plants

Algae, climbing fern and other kinds of plants are also serious weeds. As an extension of the idea of weediness, there are animals such as grackle, cockroach, and Norway rat that follow the trail of human disturbance, and even people could be considered “weedy” in that we do well in disturbed habitats.

C. Weed Ecology

11. Many weeds are r-strategists

In ecological theory developed in island biogeography, an r-strategist is an organism with many small propagules sometimes more than 200,000 per plant, often with a short generation time, and capable of primary succession into an open niche (“nature abhors a vacuum”). This kind of organism is an ecological opportunist, adapted to colonizing new and unstable or unpredictable habitats and is not well adapted to competition under scarce resources. The opposite of an r-strategist is a K-strategist which is a plant that invests more to compete in a crowded niche, and has larger and fewer propagules.

12. Weeds disperse their seed and spread by various methods

Mechanical conveyance works for seeds that are small and float on water or air (e.g., the feathery pappus of the Asteraceae), or have spines and barbs to attach to the hair of mammals. Some weeds can transport their seeds by an exploding capsule. Because of the unusual habitats provided by humans, there are plants adapted to growing on walls, the muraf flora or wall vegetation.

13. Weed seed can persist in the seed bank

The seed bank is the reserve of seeds, normally in the soil, that has not yet germinated but is viable and could germinate when conditions are right. Seed that is not ready to germinate may have dormancy which may be broken when conditions are right, usually involving soil disturbance and light and alternating temperatures. Dormancy leads to discontinuous germination which is an adaptive mechanism by which weeds survive. An important goal of weed management is to limit the buildup of weed seed in the soil, and to reduce over time the seed bank. Most seed germinate near the soil surface and shallow tillage is often effective in forcing weed seed to germinate, whereas deep tillage tends to delay germination. Some seed, especially with hard seed coat, have longer innate dormancy. The half-life, the time duration for total viability to reduce by 50%, is one way to express the longevity of seed.

14. The seed has different meanings

The seed has two intended botanical meanings, a mature ovule and a unit of dispersal, and there is also a social definitions which are expressed such as “He is a

bad seed,” and “Seeds of change” and “We will plant the seed of an idea.” While we will normally assume the first meaning, when the Irish potato is planted from tuber sections, they are usually referred to as “seed”. Weed scientists who study vegetatively propagated weeds have used the concept of a seed (corm, rhizome, tuber, turion, etc.) as a unit of dispersal. The “seed” of the sandbur is normally several spikelets fused together by the sharp reduced branches which form spines. Although the seed is only one phase of the life cycle of a weed, the seed assumes great importance because it achieves two purposes, dispersal and persistence in the soil. A large group of herbicides, preemergence, are directed to preventing seed emergence. Weed seeds are also helpful in identification.

caryopsis, achene, berry, legume, capsules, etc. – fruits types of various plants

dispersal – movement of weeds often by seeds from place to place

dormancy – state of seed in which germination is inherently inhibited

fruit – a mature ovary

embryo – the part of a seed containing the axis (shoot and root) of a new plant

emergence – the grow of a seedling above the level of the soil

exponential decay – the reduction of something in proportions over time

exponential growth – same thing as compound growth, or compound interest

germination – the production of a radicle from an embryo

half life– the length of time required for something to be reduced by one half

longevity – length of life; may be different methods of measurement (what is the best strategy for weeds, to have long or short longevity?)

propagules – a term which explicitly includes seed and vegetative propagules

longevity – length of life; may be different methods of measurement

predation – as used here, herbivorous consumption of seeds

scarification – abrasion of seed to help break dormancy

seed – a tiny embryonic plant

seed bank – the viable, ungerminated seed in the soil

viability – ability to germinate

15. Weeds spread and persist by vegetative methods

Some of the worst weeds do not spread by seed but spread largely by stems and cuttings, e.g., cogongrass, kudzu, and hydrilla, which are often carried by humans. These species must thus be fairly homogeneous genetically, which is interesting because we normally think of sexual reproduction as being fairly necessary to maintain the ability of populations to adapt to changing environments. Vegetative underground parts are important in provide persistence to torpedograss and other species and can be thought of as part of the tuber/rhizome/propagule bank.

16. Plants compete with one another for space and resources

There can be physical competition for space and resources (nutrients, water, and sunlight). Weeds and other plants also compete through allelopathy or chemical toxins (allelochemicals) that affect other plants. Sometimes an intended planting, e.g. redtop millet planted as a companion plant for roadside grassing of bahiagrass, can be so competitive that the crop, bahiagrass, does not establish. So, is millet a weed?

During the initial growth of weeds and a crop in a newly planted field, the first plant that gets established has the advantage. Plant architecture (leaf area, branching pattern, height) are important and weeds with rapid, tall, dense canopy are very competitive. Sometimes the basic characteristics of species help explain their competitive abilities under different conditions. For example, legumes (Fabaceae) that often fix nitrogen are more competitive under low nitrogen conditions.

There is much that we do not know about the interrelationship of plants growing together, both intraspecific and interspecific competition.

D. Weed Management

17. Weed management is about the same thing as controlling weeds

Despite what one author told you, weed management has the same general meaning as weed control, although management has a connotation of a larger or more comprehensive system, whereas control refers more often to the effect of a single chemical or cultural practice. In most research papers, the intention of “weed control” is “weed reduction” often based on a visual assessment. Other terminology related to reducing the damage caused by weeds includes suppress and eradicate. Some herbicide labels say that they will “control or suppress” a certain weed which is probably hedging the fact that they might not do much of anything.

18. Cultural management is a method to control or manage weeds

Cultural management is the use or adjustment of normally applied cultural practices (e.g., irrigation, fertilization, pruning, and soil practices) to reduce the losses caused by plant pests. Although there is much “lip service” given to cultural management, there is comparatively less research on cultural management of weeds than on herbicides. There has been research on the role of row spacing on weeds in field crops. Some applications such as fertilizer placement and drip irrigation can be selectively applied to the crop not the weeds. Timing is another selected method in cultural management. A newly planted field crop usually has an initial “weed-free period” of weeks when there is little or not competition from weeds. During this period any resources received by the crop will help the crop outgrow subsequent weed infestation. Later, after weeds have begun to overshadow the crop, it may be too late to have a positive impact in the competition between weed and crop. Rapid and uniform crop establishment can reduce weed infestation, in fact even in a landscape situation uneven distribution of irrigation water may make weed problems more severe. Alternatively, fallowing or intercropping, companion cropping, and various methods of rotation cropping can reduce weed populations. Cultural management can embrace a large number of practices including some that some that might be ignored, such as solarization, etc.)

19. Genetic differences exist among cultivars in weed competition

Taller varieties usually have less problem from weeds. Differences in leaf angle may also be important. Species that are poorly adapted are often prone to weed infestation.

20. Tillage is an ancient practice that continues to be very important today

Mechanical weed control includes pulling weeds by hand as well as using tillage which is the long-term historical practice of stirring the soil or cutting off the weeds by dragging something over the soil.

cultivation – two definitions: (1) tillage, (2) growing a crop

disk - tillage equipment with an array of round vertical plates that are dragged at an angle to the direction of forward movement

fallow – leave a crop area barren, and not to plant it; may be useful for long-term elimination of weeds in the soil

handweeding – removing a weed by hand, especially useful for weeds that are scattered; very effective against annual and biennial weeds.

harrow - method of tillage involving spikes that are dragged at shallow depth

hoe - a handheld tool used to sever weeds at the soil line

mulch - a vegetative soil covering which smothers weeds and prevents seedlings from emerging

plow - tillage involving deeply turning over the soil, e.g., “a moldboard plow”

soil structure – aggregation of soil particles into pedons; sand soils have no structure

tillage – the working up, or stirring of, the soil to provide soil structure and/or mechanical weed control

tilth - condition of soil that has been tilled

21. Preventative weed control is sometimes considered a fifth practice

Many weeds get established because they are brought in by people and there are several methods to prevent this, even to the point of a quarantine possibly contaminated soil or plant material. Various kinds of scouting and inspection are important to prevent weeds as well as to assess the timing of IPM practices.

E. Herbicides

22. Synthetic chemicals, herbicides, control or manage weeds

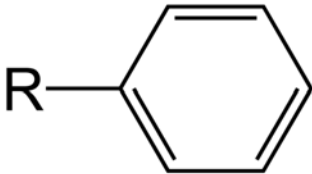
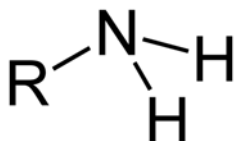
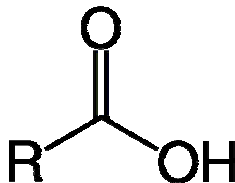
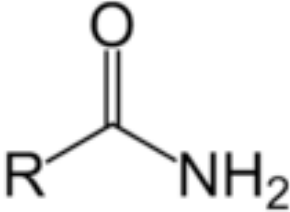
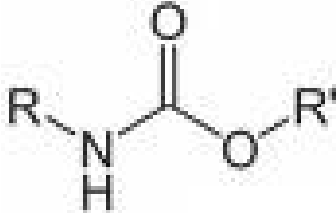
German chemists who were later joined by other nations advanced organic chemistry from the early 1800s and the early products included explosives, chemical warfare, fertilizers, dyes, plastics, and ultimately in 1943, pesticides in the form of the herbicide 2,4-D. (Other chemicals were used previously, such as copper salts for selective weed control in cereals in the late 1800s.) The age of “better living through chemistry” (a motto of Dupont) eventually shifted to a more responsible approach after the publication of Rachel Carson’s *Silent Spring* in 1962, showing the concerns about the effects on birds of the insecticide DDT, and the birth of the Environmental Protection Agency under the Nixon administration in 1970.

In 2008, herbicides are enormously important in commercial weed control, however some of the downsides, besides environmental concerns, are the large carbon footprint of petrochemical pesticides and the development of herbicide-resistant weed populations.

The basic concepts and terminology of herbicides include absorption (into the plant), translocation (through the plant), and metabolism (in the plant). Herbicides may be selective or nonselective, systemic and translocated or non-systemic and contact, soil-applied or foliage-applied, preemergence (kills seedlings after they germinate and before they emerge from the soil) or postemergence. There are also fumigants, gaseous herbicides or pesticides that usually allow nothing to survive. Herbicides are classified in 40 to 50 families.

23. Synthetic herbicides follow basic rules of organic molecular structure

The covalent bond (sharing of electrons) makes organic molecules relatively strong. There are single, double, and triple bonds that can occur between two carbon atoms. Rings such as the benzene ring (represented by the phenyl functional group) tend to be very stable. An herbicide has a basic structure with variable functional groups. The atoms of an herbicide molecule are primarily H, C, O, and N.

Base molecule	Functional group	Illustration
benzene	phenyl	
methane	methyl	$R-CH_3$
primary amine, e.g., ammonia	amino	
carboxylic acids, e.g. formic acid or methanoic acid	carboxyl	
formamide	amide	
carbamic acid	carbamate	

24. There are several methods for treating with herbicides

Boom spraying is common, often with a tractor mounted rig or a pulled sprayer, so is the application of a fertilizer-herbicide granule. Homeowners have available hose-end sprayers, and fertilizer-herbicide granules. Postemergence spot treatment can be done selectively with a nonselective herbicide, and other methods include hose sprayers, low volume sprayers, using a shroud, and aerial or aquatic application.

25. Selectivity is an important characteristic of some herbicides

Selectivity is the differential effect of an herbicide on one kind of plant compared with another kind of plant. To truly understand selectivity, it can be thought of as a continuous, usually S-shaped or sigmoidal response curve. High enough doses of a supposedly “selective” herbicide can cause injury in a crop. Can you think of an herbicide that is considered nonselective?

26. Herbicides are grouped in families with characteristics

As form follows function, herbicides with closely similar functional groups on the molecules, have similar effects on certain kinds of weeds. The Phenoxy family of herbicides is based on the phenyl ring, and many of these herbicides are very harmful to broadleaf or dicotyledonous plants, but not against grasses or other monocotyledonous plants.

27. Three kinds of names are associated with herbicides

The common chemical name, e.g., atrazine, is equivalent to the full chemical name, 6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine. The third name which is important is the trade name, e.g., Atrazine 4L, Aatrex. Other examples of common and trade names follow in the discussion of the following families.

28. Dinitroanilines (“DNA”) are common preemergence herbicides

Relatively inexpensive, the dinitroaniline herbicides were developed largely in the 1970s and as soil applied mitotic arresters due to their ability to bind to tubulin, the major microtubule protein, and preventing normal chromosome disjunction, and they can prevent seedling emergence, especially of annual grasses, but they injure roots of valuable plants. There can thus be some postemergence effect and turfgrass sod producers are sometimes reluctant to use these products because of the burned-off roots they cause, and the looping tendency in St. Augustinegrass. The basic structure is an aniline ring with a nitro (NO₂) group at the 2- and 6-positions. Common herbicides end in the suffix “in,” e.g., pendimethalin (Pre-M), oryzalin (Surflan), benefin (Balan), and trifluralin (Treflan), and also prodiamine (Barricade). They often stain sidewalks, walls, shoes, and mulch areas. A related family, the pyridines (e.g., dithiopyr or Dimension) are also microtubule assembly inhibitors and used as preemergence herbicides.

29. Phenoxy (organo auxins) were the first synthetic herbicides

Relatively inexpensive, the phenoxy growth regulator-type herbicides such as 2,4-D; 2,4-DB; and mecoprop or MCPP can cause strong distinctive growth distortions called epinasty in susceptible plants such as tomato. Ester formulations can move through the air and destroy crops 10 miles from the point of application. The administrative rule of the Florida Department of Agriculture and Consumer Services, the organo-auxin rule, limits the use of these herbicides depending on the direction and speed of the wind. The phenoxy herbicides are related to the benzoic acids which include dicamba (Banvel, Clarity).

30. Organic arsenicals are a special concern for the environment

Relatively inexpensive, organic arsenical herbicides include MSMA, monosodium methanearsenate and they cause chlorosis in many susceptible grasses and the mode of action is on the chlorophyll. The concern is based on the long-term persistence of the element arsenic in the environment, even though MSMA is a relatively stable non-toxic chemical. The EPA has determined that MSMA is ineligible for reregistration.

31. Triazines are widely used herbicides in field crops and some turfgrasses

Triazines include atrazine (many trade names) and simazine which is relatively highly water soluble and start by causing interveinal chlorosis, marginal leaf yellowing, and necrosis of young leaves, growth stimulation in St. Augustinegrass, and death of many herbaceous broadleaf plants. The mechanism of action is by affecting a protein of the photosystem II complex in the chloroplast thylakoid membranes, blocking electron transport which stops CO₂ fixation, etc.

32. Sulfonylurea herbicides are effective at extremely low doses

Sulfonylurea herbicides are relatively expensive due to patent and licensing costs and synthesis costs. This large herbicide family has many specific uses against mostly broadleaf weeds but also some sedges. For example, metsulfuron (Escort, Manor, Blade) can be used at ½ ounce formulation per acre. Other names include sulfosulfuron, halosulfuron, trifloxysulfuron, and foramsulfuron. The mechanism of action is inhibition of acetolactate synthase, so they are called ALS inhibitors. ALS is a key enzyme in the biosynthesis of the branched-chain amino acids isoleucine, leucine, and valine. They are very adsorbant to organic matter (OM).

33. The herbicide label goes beyond telling the user how to apply

The herbicide label includes human and environmental safety precautions, reentry intervals, allowable or prohibited mixtures and many other details that must be read and abided by.

34. The formulation of an herbicide active ingredient is very important

Some of the things that are not mentioned on the herbicide label are the carrier, adjuvants, and other active chemicals that are not considered the “active ingredient.” Whereas by law the active ingredient must be mentioned on the label,

many of these other components of an herbicide are merely labeled “inert ingredients” but they are proprietary so the manufacturer will not tell you what they are.

35. There are letter symbols for different formulations, G, EC, etc.

The most common abbreviations are DF, dry flowable; EC, emulsifiable concentrate; G, granular; L, liquid; WDG, water dispersible granules; WP, wettable powder; WS, water soluble; and WSP, water soluble packets.

36. Herbicides may have several different environmental fates

Leaching, decomposition, photodecomposition, adsorption, microbial degradation, runoff, and volatilization are several of the possible fates. Herbicides may be absorbed to the roots or the foliage of plants. Drift injury from the herbicide 2,4-D can occur 10 miles from the point of application.

37. The label is the law

The specific label associated with each pesticide is to be used and there are up to 15 elements, (1) restricted use pesticide statement; (2) product name, brand or trademark; (3) ingredient statement; (4) keep out of reach of children; (5) signal word; (6) first aid statement; (7) "skull & crossbones" symbol and the word "poison"; (8) net contents and net weight; (9) EPA registration number (the single most important piece of information for tracking pesticide products) and the establishment number (identifies the final physical location where the pesticide product was produced or labeled); (10) company name & address; (11) precautionary statements (hazards to humans and domestic animals, first aid, environmental hazards, and physical or chemical hazards); (12) directions for use; (13) storage and disposal instructions; (14) warranty statement; (15) worker protection labeling. The label should tell you of any special incompatibilities including mixtures of herbicides.

38. Good sprayer calibration is essential in getting it right the first time

Three and only three facts are needed to determine carrier rate per area, e.g., gallons per acre, and they are the ground speed, the distance between nozzles on the boom, and the spray capture rate in volume per time. Other useful information that is helpful in assuring an accurate spraying, but that is not helpful in calibration, is nozzle discharge pressure, e.g., pounds per square inch, type of nozzles, and boom height.

39. Environmental conditions can prevent safe and effective spraying

Normally, the applicator should spray pesticides when the wind is less than 5 miles per hour, certainly less than 10 miles per hour, depending on the spray droplet size and the elevation of the spray nozzles above the ground, and whether there is shielding. Other environmental conditions such as temperature and rain can have a major effect on the success or failure of herbicide spray applications.

E. Fun with Weeds

40. You can take good pictures of ephemeral plants and identify them

Landscape weeds are commonly illustrated to aid in their identification. Color photos and pen-and-ink drawings have assisted golf course superintendents, ranchers, and natural resources managers in making comparisons to an unknown plant sample, and thereby assigning a species name if there is a match to an unknown plant sample. During the 1990s the expansion of the internet, email attachments, and digital images increased the power of illustration in the identification and study of weeds.

While it is easy to digitally capture and distribute weed images, the new technology raises issues which existed before the digital age:

- Reference image sets may incompletely represent South Florida weeds
- Digital image quality in reference sets and those that I receive by email of unknown samples are often of unsuitable quality
- The manner by which image sets are organized can influence the efficiency of identification of unknown samples
- Digital images present new problems in preservation
- With most forms of illustration the "elephant in the room" is the fact that these are 2-dimensional representations of 3-dimensional organisms

While the illustrations in most current publications, such as "Weeds of southern turfgrasses" are strictly color photos, some of the best plant illustrations have been black-and-white, pen-and-ink drawings. Artist Regina Olson Hughes (1895-1993), of the USDA and later Smithsonian Institution, illustrated "Selected weeds of the United States" (Agricultural Handbook 366, 1970). What makes pen-and-ink drawings so effective is that they remove the plant from the distracting background and they enhance the contrast of diagnostic features such as veins and trichomes that might not otherwise stand out.

The illustration of plants is an ancient activity among those cultures which have shown curiosity and have appreciated the practical and esthetic value of plants. In predynastic Egypt, time boats carved onto pottery were illustrated with a palm tree indicating the end of a year. From at least 2000 B.C. the Mesopotamian kings had a keen interest in exotic plants and animals, many of which were imported, described, and carved in relief on monuments. As a result of such illustrations modern scientists can identify many of the plant species used in the Hanging Gardens of Babylon. Probably the earliest depiction of plants was from the 4th millennium BC on the Sumerian Vase of Uruk, also called the "Warka Vase" in which is depicted offerings to Inanna (Innin), Goddess of fertility, during the New Year Festival. The story read from the bottom of the vase water, crops such as barley and perhaps sesame, sheep, humans, and the Goddess accepting an offering. Inanna who derived

from the Sumerian Goddess Nin-anna for "the lady of heaven" later became the Semitic Goddess Istar.

During the Caliphate of Córdoba in the 10th century in present day Spain, there was an abundance of botanical illustration as part of the multicultural (Christian, Jewish, and Muslim) flourishing of science and medicine. Important scientific works by Aristotle and Dioscorides were translated from Greek, and therapeutic plants were illustrated. The Medieval herbals continued to be copied and recopied by hand until the invention of the printing press made it much easier to reproduce plant illustrations. The herbarium which arose during the early 1500s became a repository for non-virtual pressed specimens of plants helpful to taxonomists, but not generally accessible to practitioners.

With the rapid development of emulsion photography in the early 1800s and later digital imaging in the 1980s the technology to create, store, and distribute accurate biological illustrations became easier and more accessible. Kodachrome film which was introduced in 1935 as the first commercially produced amateur film made it possible to create long-lived positive transparencies, and scientists maintained "slide sets" of favorite subjects. This also made it more possible to create plant identification booklets with color images.

During the 1960s NASA converted from analog to digital signals with their space probes and by the 1990s CCD (charge coupled device, first invented at Bell Laboratories in 1969) photography was accessible to amateur astronomers. In 1990 Kodak introduced the photo CD camera, and the first digital cameras for the consumer level market were introduced by Apple in 1994.

In 1989 Dr. Bill Howard used the Fax machine, which had become common in the late 1980s, to send an image of a grasshopper for identification. The easy sending of digital photographs became a reality in 1996 when RFC 2045 described the MIME protocol (Multipurpose Internet Mail Extension). Although email was first invented in 1972, based on the Arpanet of 1969, it did not become prolific until after the U.S. government released control of the internet for commercial purposes in 1994. The Clinton-Gore administration had pushed very hard on what they had called the Information Superhighway, and pressed federal agencies to make digital information available on the internet, launching the first official White House website on 21 October 1994.

While use of email within the protocol Bitnet did not come to most of us at the Center until 1991, thanks to the Vax network, since at least 1997 many of us have used email attachments. On October 16, 1997, I first sent a photo by email which was an image of the larva of the snout weevil, *Oxyops vitiosa*, that my daughter Katie had taken. For the last 10 years that image remains on the Cornell University web site.

http://www.nysaes.cornell.edu/ent/biocontrol/weedfeeders/oxyops_vitiosa.html

Semi-automatic plant recognition has been attempted for specific flower features such as bloom color, inflorescences, shape of blooms, and number and shape of petals. Not surprisingly, "the 3D analysis of shapes and structures is difficult to be obtained from 2D images."

Now that plant illustrations by digital photographs have become normal it is desirable to review some of the basic concepts of photo composition, both from a standpoint of esthetics but also usefulness in identification.

The problem is that many diagnostic photos including weed photos do not show enough of the subject to make identification easy.

Composition and use of weed images

Here is an adaptation of basic photo composition rules pertinent to plant photos:

- Use silhouettes to improve the contrast of the subject and its background. Sometimes a weed can be photographed in the sunlight, with a shaded background.
- Use depth of field to guide the viewer, by blurring out the background.
- Use a wide angle lens to capture both the context and the subject.
- Use familiar objects for scale
- Consider time of day and lighting conditions to enhance contrast.
- Compose images to show multiple diagnostic parts.

By whatever method of representation, both whole plant images and close representations of diagnostic plant parts are used for identification. Pocket guidebooks and other printed and digital formats for weed identification often contain accessory information to help in identification and to inform the method of controlling particular invasive plant species.

Textual information may mention plant odor, phenology, ecological associations, color, nuisance properties, and other plant characteristics that may not be sufficiently represented in the illustrations.

Dichotomous keys have been used traditionally to assist in weed identification. Some online machine methods allow the observer to indicate what traits are present. Sometimes the photos of weeds are quite useful in identification, but for many of the images that I receive there is not enough information in the photograph.

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